2614

RECEIVED #4

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE JUN 2 9 2001
Group Art Unit 2614

Technology Center 2600

In re

Patent Application of

Martin Weston
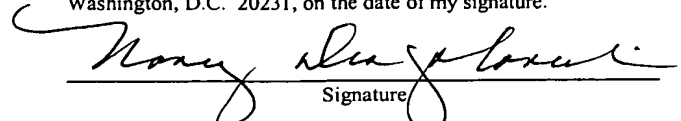
Serial No. 09/826,392

Filed: April 4, 2001

"SPATIAL VIDEO PROCESSING"

SUBMISSION OF PRIORITY DOCUMENT

RECEIVED

JUN 2 9 2001

Technology Center 2600

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Enclosed is the priority document for the above-identified application.
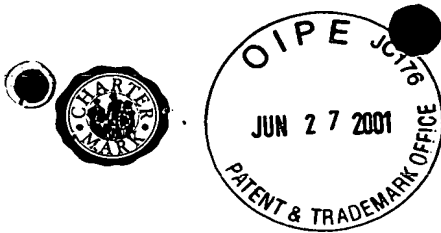
Respectfully submitted,

Derek C. Stettner
Reg. No. 37,945

File No. 87805-9025

Michael Best & Friedrich LLP
100 East Wisconsin Avenue
Milwaukee WI 53202
(414) 271-6560

THIS PAGE BLANK (USPTO)

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

INVESTOR IN PEOPLE
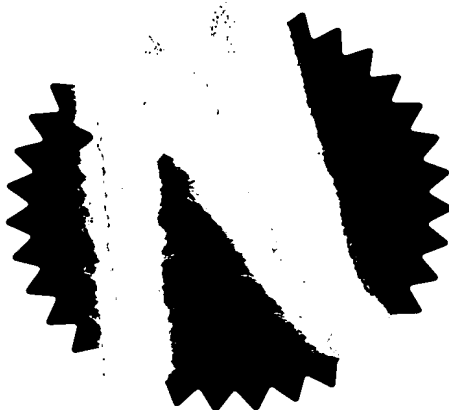
I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely sul ·~cts the company to certain additional company law rules.

Signed

Dated

28 MAR 2001

An Executive Agency of the Department of Trade and Industry

THIS PAGE BLANK (USPTO)

The Patent Office

Request for grant of a patent LONDON
*(See the notes on the back of this form. You can also get an
explanatory leaflet from the Patent Office to help you fill in
this form)*

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	PDG/22144

06APR00 E527481-3 D02000
P01/7700 0.00-0008402.0

2. Patent **0008402.0**
(The Patent Office ...)

U 5 APR 2000

P01/7700 0.00-0008402.0

3. Full name, address and postcode of the or of
each applicant *(underline all surnames)*

Snell & Wilcox Limited
6 Old Lodge Place
St Margaret's
Twickenham
Middlesex TW1 1RQ
United Kingdom 5579784003

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the
country/state of its incorporation

4. Title of the invention

SPATIAL VIDEO PROCESSING

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom
to which all correspondence should be sent
(including the postcode)

MATHYS & SQUIRE
100 Gray's Inn Road
London WC1X 8AL
United Kingdom

Patents ADP number *(if you know it)*

1081001

6. If you are declaring priority from one or more
earlier patent applications, give the country
and the date of filing of the or of each of these
earlier applications and *(if you know it)* the or
each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise
derived from an earlier UK application,
give the number and the filing date of
the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right
to grant of a patent required in support of
this request? *(Answer 'Yes' if:*
a) *any applicant named in part 3 is not an inventor, or*
b) *there is an inventor who is not named as an
applicant, or*
c) *any named applicant is a corporate body.*
See note (d))

YES

Patents Form 1/77

9. Enter the number of sheets for any of the
   following items you are filing with this form.
   Do not count copies of the same document

   Continuation sheets of this form   —

   Description   6

   Claim(s)   1

   Abstract   —

   Drawing(s)   4

10. If you are also filing any of the following,
    state how many against each item.

    Priority documents   —

    Translations of priority documents   —

    Statement of inventorship and right
    to grant of a patent (Patents Form 7/77) —

    Request for preliminary examination   1
    and search (Patents Form 9/77)

    Request for substantive examination   —
    (Patents Form 10/77)

    Any other documents   —
    (please specify)

11.   I/We request the grant of a patent on the basis of this application.

                                              Signature   Date

                                              MATHYS & SQUIRE   5 April 2000

12. Name and daytime telephone number of
    person to contact in the United Kingdom

                                              Peter D Garratt - 020 7830 0000

Warning

*After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication
or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You
will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the
United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting
written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the
United Kingdom for a patent for the same invention and either no direction prohibiting publication or
communication has been given, or any such direction has been revoked.*

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.

b) Write your answers in capital letters using black ink or you may type them.

*c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate
sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be
attached to this form.*

d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) For details of the fee and ways to pay please contact the Patent Office.

SPATIAL VIDEO PROCESSING

This invention relates to video processing and particularly to spatial video processing. An important example is the creation of additional lines through spatial interpolation.

A spatial interpolation filter has a filter aperture comprising an
5   appropriate number and arrangement of neighbouring pixels and takes a weighted sum of contributions from pixels within that filter aperture. It has previously been recognised that such a filter can introduce smearing if there are pronounced slopes in the picture material. It is instructive to take the example of a striped image. A filter designed to take weighted sums of
10   contributions along a horizontal pixel line will be expected to function correctly as long as the stripes in the image are horizontal. Essentially, weighted averages are taken along the stripe and therefore from pixels which are similar. If diagonal stripes are encountered, a weighted sum of contributions along a horizontal pixel line will now mix pixels which are from different stripes
15   and which may be very different. Smearing of the image is likely to result.

One approach to this problem is to avoid using spatial interpolation and instead to utilise temporal interpolation. This might work well for stationary pictures but is unlikely to be a satisfactory solution where there is movement between successive pictures.

20   It has been proposed to improve spatial interpolation by measuring pronounced slopes in the picture material and then rotating the filter aperture into alignment with the measured slope. In the example of diagonal stripes, the angle of the stripe is measured and the filter aperture rotated so that weighted contributions are taken along the stripe, from pixels that remain
25   similar. This proposal can be very helpful if the slope is measured accurately and the filter rotated into precise alignment. This can however be a complex operation. Moreover, if the filter is rotated by the wrong amount, the results can be as bad as, or sometimes worse than, if the aperture remained static. It is also a factor that if the filter aperture is to be able to accommodate shallow
30   slopes (and it is shallow slopes that produce the most objectionable artefacts), a very wide filter aperture is required.

It is an object of this invention to provide improved video processing in which slopes are accommodated with greater tolerance to errors or variations in slope angles.

It is an object of one form of this invention to meet the performance of prior art slope processing with substantially smaller filter apertures.

Accordingly, the present invention consists in one aspect in video processing apparatus comprising a set of spatial filter apertures and a slope detector, the apparatus selecting the appropriate filter aperture in accordance with the output of the slope detector and taking weighted contributions from pixels in the selected filter aperture, wherein the filter aperture weightings sum to unity over a line including the current pixel and sum to zero over either side of the said line.

Suitably, said line is vertical.

Advantageously, the set consists of three spatial filter apertures.

In another aspect, the present invention consists in video processing apparatus comprising a slope detector and a spatial filter having a positive filter aperture, a linear filter aperture and a negative filter aperture; wherein the positive filter aperture is employed upon detection of any positive slope in excess of a defined positive threshold; the negative filter aperture is employed upon detection of any negative slope in excess of a defined negative threshold; and the linear filter aperture is employed otherwise.

Advantageously, in each said filter aperture weighted contributions are taken from pixels with the filter aperture weightings summing to unity over a line including the current pixel and summing to zero over either side of the said line.

Suitably, said line is vertical.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a diagram showing the pixel weightings for a known linear filter;

Figure 2 is a diagram showing the pixel weightings for a positive slope filter aperture according to an embodiment of the invention;

Figure 3 is a diagram showing the pixel weightings for a negative slope filter aperture according to an embodiment;

Figure 4 is a diagram illustrating the manner of operation of the described embodiment; and

Figures 5 to 8 are diagrams illustrating an adaption process according to an embodiment of the invention

The example will be taken of vertical interpolation. If a four tap vertical filter - such as that shown in Figure 1 - is used to vertically interpolate an interlaced picture the resulting image will be soft with various artefacts. One of the most noticeable artefacts is jagging on diagonal lines. Attempts have been made to try and reduce this jagging by twisting the vertical filter so it filters along the direction of the slope of the diagonal line. This will remove the jags, but such a filter is very dependent on knowing the exact slope of line, which is difficult to measure.

A preferred embodiment of the present invention uses a set of three filters. Rather than twisting the simple vertical filter of Figure 1 to interpolate along the direction of the slope, a switch is made to the filter of Figure 2 for a positive slope and to the filter of Figure 3 for a negative slope. (The terms, positive slope and negative slope, in a picture, are often found confusing. In this specification, the nomenclature that is used denotes as positive a slope which rises vertically, from left to right.)

It can be seen that the filters of Figures 2 and 3 use high frequency contributions from horizontally displaced pixels. Thus weightings of the contributions from the central vertical line are the same as in the simple vertical filter and sum to unity. The weightings on either side of that line, sum to zero. High frequency information from adjacent pixels is thus being used to reduce jags in the image.

A possible explanation for the excellent results achieved with this arrangement is that it allows the removal of jags from edges that are very nearly horizontal (the most objectionable), using a fairly small aperture. Twisting the aperture to interpolate along the edge would require a much larger aperture.

Referring to Figure 4, consider the picture contains a sloping edge, denoted by the solid vertical line. The voltage across the edge varies as shown by the marked parabola. If a vertical [0.5 0.5] filter were used the resulting interpolated voltage would be (b+f)/2, which is considerably larger than the correct result, d. If the aperture were skewed along the diagona,l the resulting voltage would be (c+e)/2. In order for this to give the correct result the aperture would have to be 16 pixels wide horizontally. However, using the slope filter according to this embodiment of the invention, the interpolated voltage is (b+f-a+c-g+e)/2, which gives the correct answer.

In one embodiment, the adaption or switch between the positive, linear and negative slope filter apertures is effected as follows. The positive and negative gradients of the input picture signal are first calculated. The difference of these two values is then calculated, giving a gradient difference or switching signal. This signal is then filtered horizontally and vertically to produce a sort of threshold signal. This filtering step also increases the aperture size, considering pixels other than the particular ones specifically analysed in the slope filters, thereby ensuring that the adaption treats a broad range of slopes. If the threshold signal is within a specified range, the usual linear filter is used. However, if it is above this range, the positive slope filter is used, and similarly, if it is below, the negative filter is preferred.

In more detail, the adaption process includes the following steps:-

- Calculate the positive gradient (g_p) using the filter shown in Figure 5

- Calculate the negative gradient (g_m) using the filter shown in Figure 6

- Calculate the difference (d) of the absolute value of these two signals
  $d = (\ \text{abs}(g_p) - \text{abs}(g_m)\ )$

- Filter using 0.25 0.5 0.25 vertically and 0.25 0.5 0.25 horizontally to give f_d

- Threshold signal f_d to form positive slope switching signal for $f_d > 5$, negative slope switching signal for $f_d < -5$ and linear switching signal for $-5 < f_d < 5$

It is advantageous that the gradient filters detect a range of slopes, which is why they are filtered vertical and horizontally by the 0.25 0.5 0.25 filters. Although this increases the aperture size of the mode selection filters (see Figure 7) it produces a worthwhile improvement in picture quality.

The above adaption process is equivalent to dividing the the gradient space into the areas shown in Figure 8. It will be recognised that this is only one example of a thresholding arrangement and modifications will be possible.

Slope orientation filtering has been shown to give a significant improvement on picture quality over linear filtering. It does not appear to introduce significant artefacts and operates to reduce jagging without softening the picture. Although the described slope filters appear to work very well, alternatives are possible. In certain applications it may be appropriate to have more than one positive slope filter and more than one negative slope filter, with each filter aperture still having the feature that the pixel weightings sum to unity over the central line of the aperture and sum to zero over all pixels on each side either side of the central line.

Although the example has been taken of vertical interpolation, this invention encompasses other spatial filter operations and orientations other than vertical. In, for example, a horizontal interpolation filter according to this invention, pixel weightings would sum to unity over the central horizontal line of the aperture and sum to zero over all pixels on either side of the central line.

Similarly, although the adaption signal described here behaves reasonably well, numerous alternatives are possible. It will often be useful to include a temporal filter aperture, for use in place of the described spatial apertures, where there is no detected motion.

Some applications may require both de-interlacing and temporal interpolation. If this is the case there are a number of possible methods.

1. De-interlace first, followed by temporal interpolation – the disadvantage with this is the need to store the 1st field.

2. De-interlace both fields at once and then temporally interpolate.

3. Include the temporal interpolation into each of the three adaption filters. In this case you would use the same adaption control for each temporal phase.

It should be understood that this invention has been described by way of examples only and that a wide variety of further modifications are possible without departing from the scope of the invention.

CLAIMS

1. Video processing apparatus comprising a set of spatial filter apertures and a slope detector, the apparatus selecting the appropriate filter aperture in accordance with the output of the slope detector and taking weighted contributions from pixels in the selected filter aperture, wherein the filter aperture weightings sum to unity over a line including the current pixel and sum to zero over either side of the said line.

2. Apparatus according to Claim 1, wherein said line is vertical.

3. Apparatus according to Claim 1 or Claim 2, wherein the set consists of three spatial filter apertures.

4. Video processing apparatus comprising a slope detector and a spatial filter having a positive filter aperture, a linear filter aperture and a negative filter aperture; wherein the positive filter aperture is employed upon detection of any positive slope in excess of a defined positive threshold; the negative filter aperture is employed upon detection of any negative slope in excess of a defined negative threshold; and the linear filter aperture is employed otherwise.

5. Apparatus according to Claim 4, wherein in each said filter aperture weighted contributions are taken from pixels with the filter aperture weightings summing to unity over a line including the current pixel and summing to zero over either side of the said line.

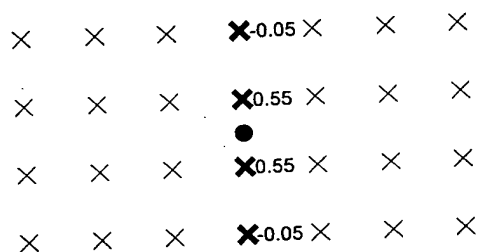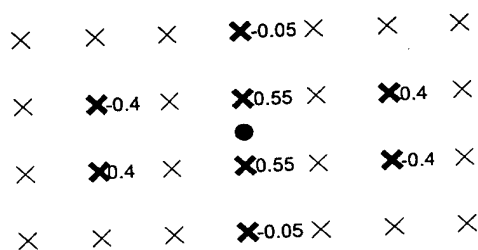6. Apparatus according to Claim 5, wherein said line is vertical.

$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

$\times$ $\times$ $\times$ $\times$0.55 $\times$ $\times$ $\times$

$\bullet$

$\times$ $\times$ $\times$ $\times$0.55 $\times$ $\times$ $\times$

$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

Figure 1: Linear aperture

$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

$\times$ $\times$-0.4 $\times$ $\times$0.55 $\times$ $\times$0.4 $\times$

$\bullet$

$\times$ $\times$0.4 $\times$ $\times$0.55 $\times$ $\times$-0.4 $\times$

$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

Figure 2: Aperture for positive slope

$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

$\times$ $\times$0.4 $\times$ $\times$0.55 $\times$ $\times$-0.4 $\times$

$\bullet$

$\times$ $\times$-0.4 $\times$ $\times$0.55 $\times$ $\times$0.4 $\times$

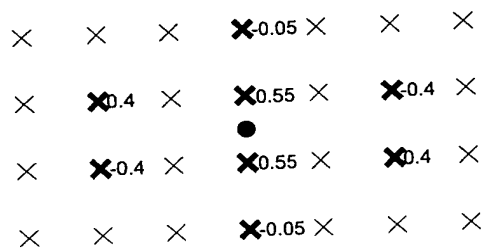$\times$ $\times$ $\times$ $\times$-0.05 $\times$ $\times$ $\times$

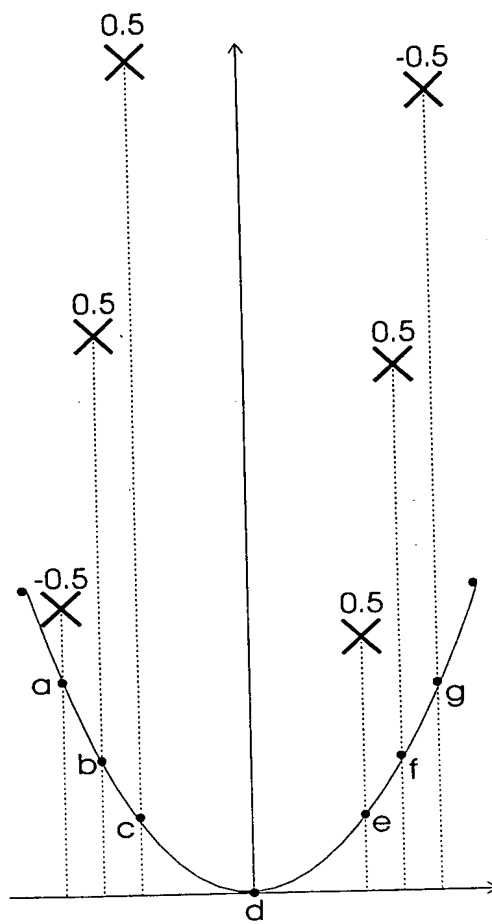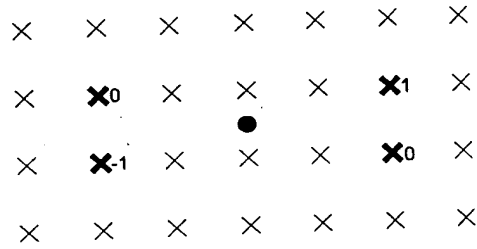Figure 3: Aperture for negative slope
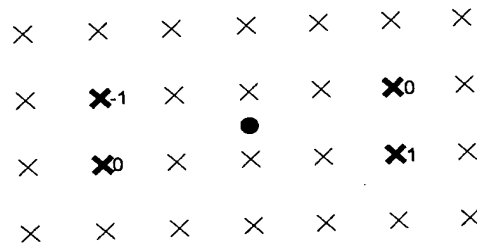
Figure 4:

Figure 5: Gradient to detect positive slope

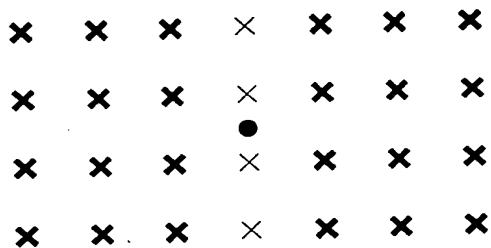Figure 6: Gradient to detect negative slope

Figure 7: Aperture size for gradients

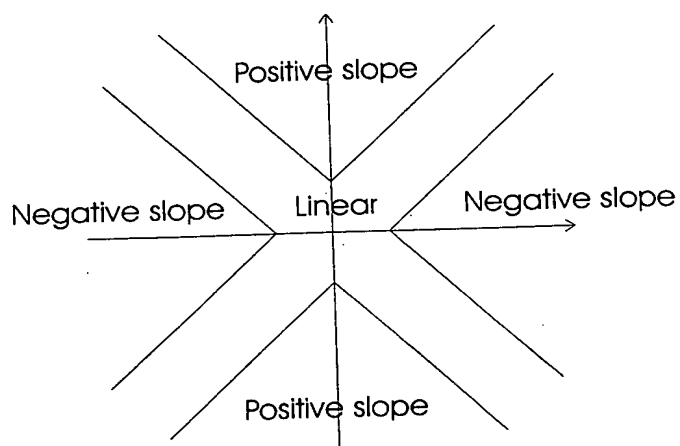Figure 8: Adaption control